Update on U.S. Drinking Water and Water Quality Research

米国の水道及び水質に関する最近の動向

Sally Gutierrez, U.S. EPA

米国環境保護庁　サリー・グティアレツ

7th Japan - U.S. Conference on Drinking Water Quality Management and Wastewater Control

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Update on U.S. Drinking Water and Water Quality Research

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Outline of Presentation

- Drinking water distribution system issues
- Drinking water source water protection
- Microbial source tracking
- Verification of ballast water treatment technologies

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Drinking Water Distribution Systems

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Drinking Water Distribution Systems Current Research

- High lead levels in Washington D.C.
- Corrosion and pinhole leaks
- Distribution system biofilms
- Arsenic accumulation in distribution systems

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High Lead Levels in the Drinking Water in Washington D.C.

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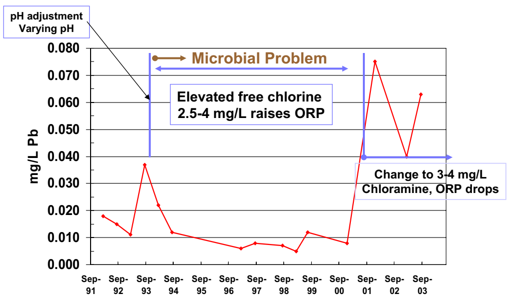
90th Percentile Pb Values



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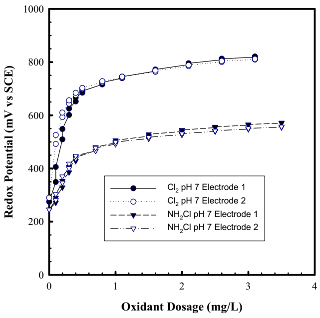
Effect of Oxidant on ORP @ pH 7



Add approximately 200 mV to get to SHE values

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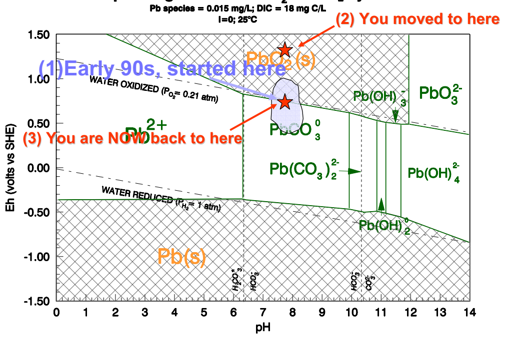
WHY IT HAPPENED; Eh change due to disinfection change:



(DIC based on Cincinnati value, about the average for D.C.)

Lead Research Summary

Field and Laboratory Studies

- **Pb oxidation state and corrosion scale geochemistry (solubility) controlled by Eh and water chemistry**
  - Relatively insoluble Pb(IV) (namely PbO_2) favored in high Eh water (e.g., well chlorinated water)
  - More soluble Pb(II) solids favored in lower Eh (e.g., chloraminated water)
  - In DC (and a few other locations) both oxidation states found in corrosion scales on lead service lines
- Pb oxidation state appears to be reversible and sensitive to Eh changes
- All current lead control strategies based on Pb(II) chemistry
- Many unknowns including: Pb(IV) chemistry in water, Pb (IV)-(II) reversion rate, role of particles, role of corrosion inhibitors, etc..

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Copper Pitting Corrosion and Pinhole Leaks

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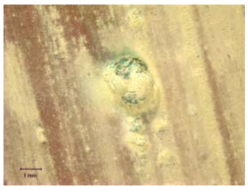
Localized Corrosion (Pitting)



Pitting is a localized acceleration of corrosion that results in the thinning of the pipe wall in the effected area.

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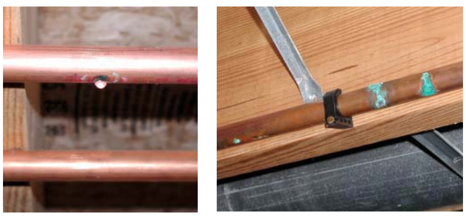
Pinhole Leaks



Pinhole leaks resulting from copper pitting

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Objective

- Closely examine copper pipes that have signs of pitting corrosion using solids analysis techniques
- Suggest mechanism of pitting corrosion

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Localized Corrosion (Pitting)

- Type I – Cold Water Pitting
  - Attacks horizontal runs of cold water pipes in systems using well waters with a high sulfate to chloride ratio
- Type II – Hot Water Pitting
  - Occurs in hot water with a pH below 7.2
- Type III – Soft Water Pitting
  - Occurs in soft water below pH 8.0

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General Observations

- Cold water
- Horizontal runs of pipe
- $\frac{3}{4}$" pipe
- Homes are about 7 years old
- Leaks occur near elbows and joints as well as in long runs
- No preference for the top or bottom of a pipe

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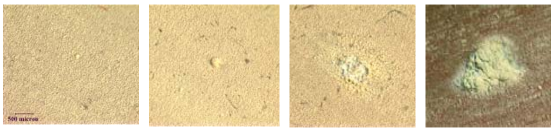
Pit Propagation



Particle deposition, particle growth, and corrosion cell formation

All pictures taken at same magnification

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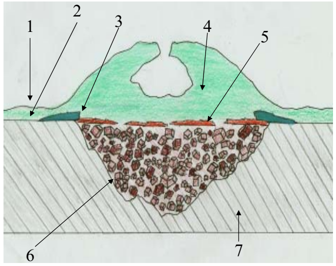
Schematic View of a Copper Corrosion Pit



1. Diffusion Barrier – Calcium Carbonate
2. Uniform Corrosion Scale
3. Cu, Al, Si, Mg rich solid
4. Corrosion Cap – Bronchantite [$Cu_4(OH)_6(SO_4)$], Ponsjakite –[$Cu_4(OH)_6(SO_4)*H_2O$
5. Brittle Perforated Membrane
6. Corrosion Pit Filled with Cuprite
7. Pipe Wall

Drinking Water Distribution System Biofilms

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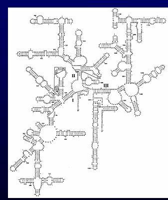
Experimental Objectives

- Compare biofilm populations exposed to HOCl or NH_2Cl
- Examine biofilms for the presence of opportunistic pathogens



Findings

- Similar populations in both chlorinated and non-chlorinated biofilms (Cincinnati water)
  - acclimated to chlorine
  - low TOC
- Sequences similar to those found in previous study of Cincinnati drinking water
- Biological activity removed NH2Cl residual
- Chloraminated biofilm dominated by *Mycobacterium* and *Dechloromonas* species

Concentration of Arsenic in Distribution System Solids

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Objective

- **Determine the composition of solids collected from distribution systems where measurable amounts of arsenic in the finished water**
  - **pipe sections (corrosion products, deposits, etc.,)**
  - **fire hydrant flush (loose particles, corrosion products, etc.,)**

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Fire Hydrant Flush

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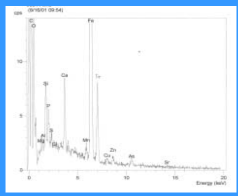
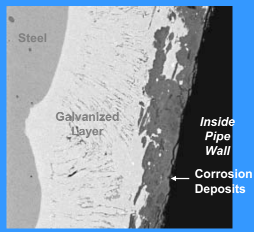
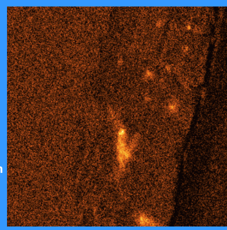
PVC pipe- Sample 3-1



Location	Sample ID	Mg (ug/g)	Si (ug/g)	P (ug/g)	Ca (ug/g)	Mn (ug/g)	Fe (ug/g)	As (ug/g)	ug As/ mg Fe
Utility 3	Sample 3-1	1492	10452	15410	22939	5141	442528	13650	30.85

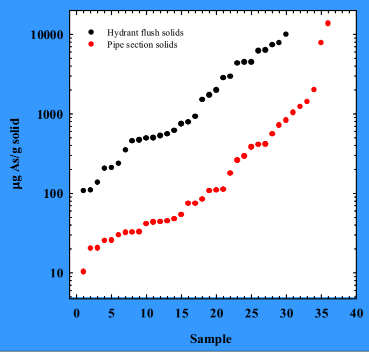
Elemental Mapping- Microprobe-WDS analysis





Arsenic distribution

Summary of the Arsenic Composition of Solids



Arsenic Composition Relationships

- Initial arsenic- no
- Pipe or flush- no
- Water chemistry- no
- Treatment- no
- Material age- ??

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Findings

- Arsenic does concentrate in distribution systems
- Amount of arsenic was independent of variables considered in this study
- Other contaminants may also behave as arsenic

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Source Water Protection

A Methodology to Evaluate the Effectiveness of Non-point Source Pollution Abatement Programs

Upper Big Walnut Creek Watershed

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Project Goal

Develop a methodology for evaluating the performance of watershed-scale non-point source pollution abatement programs.

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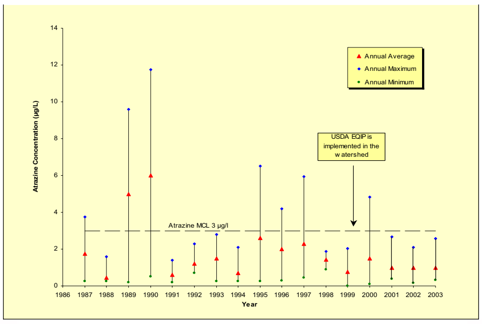
Long-Term Water Quality Data Identifies Concern



Source: City of Columbus, Division of Water, Water Quality Assurance Lab

BMP Implementation Program

1999 Program BMP Implementation Analysis*

Practice	Incentive Rate	Acres Enrolled	Cost
Conservation Tillage			
Corn	**$ 8/acre**	**163 (5.2%)**	**$ 1,309 (4.5%)**
Soybeans	$ 8/acre	63 (2%)	$ 501 (1.7%)
Wheat	$ 8/acre	332 (10.6%)	$ 2,655 (9.1%)
Crop Rotation (wheat)	$ 5/acre	341 (11.2%)	$ 1,706 (5.9%)
Residue Management	$ 5/acre	58 (1.8%)	$ 288 (1%)
Pesticide Management	**$15/acre**	**1,498 (48.2%)**	**$ 22,477 (77.7%)**
Nutrient Management	$ 0/acre	3,108 (100%)	$ 0
Precision Farming	$ 1/acre	0	$ 0
TOTAL		**3,108****	**$ 28,938**

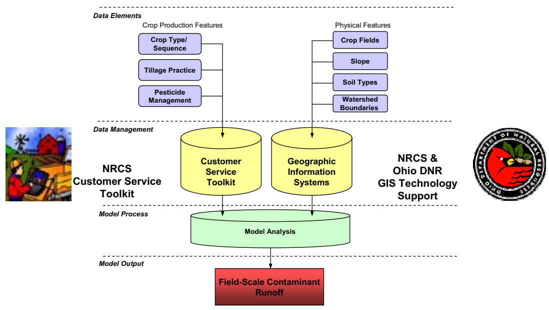
* First of five-year cost-share allocation
** Approximately 4.3% of total watershed cropland acres

Critical Question:
Do these practices achieve water quality goals?

Project Approach

Task 1: *Project Management*
Task 2: *Information Management Systems*
Task 3: *Evaluate and Select Models*
Task 4: *Establish Benchmark Conditions*
Task 5: *Evaluation of EQIP*
Task 6: *Recommendations*
Task 7: *Documentation*

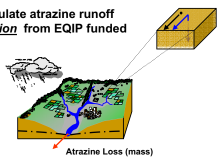
Task 2: Information Management Systems



Source: EPA, 2003. National Management Measures for the Control of Nonpoint Pollution from Agriculture

Task 5: Evaluation of EQIP Program

1) Simulate atrazine runoff *reduction* from EQIP funded BMPs



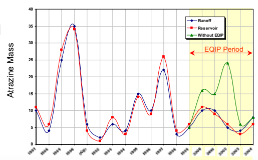
2) Calculate annual Hoover Reservoir atrazine load using empirical model

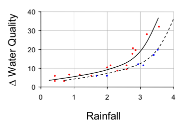
$\Delta Mass = [(C_f \times V_f) + [(C_i + C_f) / 2 \times V_{(Di\to f)}] - C_i \times V_i] V_f$

where;

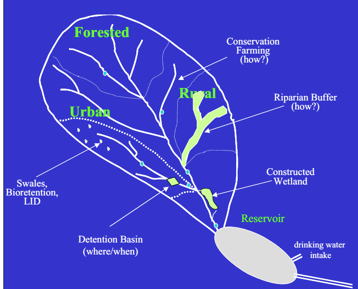
ΔMass = Estimated atrazine load to Hoover Reservoir

3) Compare changes between model runoff loss and annual Hoover Reservoir atrazine load





Management Practices: Deciding when, what kind, where, how, and if they work.



Unit operations embedded in the watershed-scale management paradigm

Microbial Source Tracking

Background

- 13% of U.S. waters impaired due to fecal contamination (2000)
- Over last 3-5 years, microbial source tracking use has increased dramatically across US
- The methods are being used to try and identify sources of fecal pollution in waters impaired due to fecal pollution
- Investment increasing

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Characteristics for Effective Source Identification

✓Accuracy
✓Robustness
✓Universality
✓Quantification
✓Inexpensive
✓Rapid

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Types of source identification methods

- Library Dependent vs Library Independent
- Phenotypic vs Genotypic
- Presence/absence vs Quantitative

Simpson, JM, DJ. Reasoner, JW. Santo Domingo. 2002. Microbial Source Tracking: State of the Science. Environ. Sci. Technol. 36:5279-5288.

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Library Dependent Methods

- Requires culturing of organisms
- *<u>Library</u> = "Fingerprint" database of E. coli or fecal enterococci methods*
- *<u>Requisite</u> = Large number of isolates (1000s!) from water samples and suspected animal sources*

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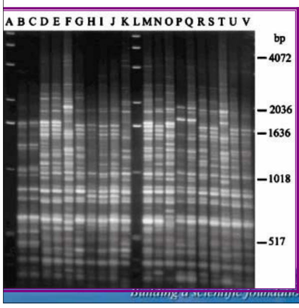
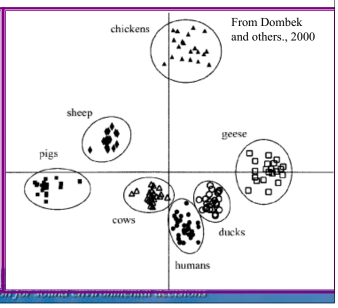
Library-dependent methods

From this ... to this





Library Independent Methods

- Culture independent
- No libraries
- Host Specific PCR
  - Fecal anaerobes
  - Viruses
  - Toxin genes

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Verification of Ballast Water Treatment Technologies

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Environmental Technology Verification Program

Program verifies the performance of commercially ready treatment technologies according to stakeholder established test protocols

ETV

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Ship Ballast Water Treatment

ETV

Test Design

Parameter	Timing
Core	
• Salinity	Continuous
• Total suspended solids (TSS)	Discrete
• Particulate organic material (POM)	Discrete
• Dissolved organic material (DOM)	Discrete
• Dissolved oxygen (DO)	Continuous
• Indigenous species	Discrete
• Surrogate species	Discrete
• O&M Factors	Continuous/Discrete
Additional	
• Turbidity (NTU)	Continuous
• Chlorophyll-a	Continuous
• Adenosine triphosphate (ATP)	Discrete

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